JAPAN

☞ EDICT OF GOVERNMENT ☜

In order to promote public education and public safety, equal justice for all, a better informed citizenry, the rule of law, world trade and world peace, this legal document is hereby made available on a noncommercial basis, as it is the right of all humans to know and speak the laws that govern them.

JIS Z 4511 (2005) (English): Methods of calibration for exposure meters, air kerma meters, air absorbed dose meters and dose-equivalent meters

安 併

The citizens of a nation must honor the laws of the land.

Fukuzawa Yukichi

BLANK PAGE

BLANK PAGE

JIS

JAPANESE INDUSTRIAL STANDARD

Translated and Published by
Japanese Standards Association

JIS Z 4511 : 2005

(JEMIMA/JSA)

Methods of calibration for exposure meters, air kerma meters, air absorbed dose meters and dose-equivalent meters

ICS 17.240
Reference number : JIS Z 4511 : 2005 (E)

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Electric Measuring Instruments Manufacturers' Association (JEMIMA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS Z 4511** : 1999 and **JIS Z 4511** : 2001 (Amendment 1) are replaced with this Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

Date of Establishment: 1975-07-01

Date of Revision: 2005-03-20

Date of Public Notice in Official Gazette: 2005-03-22

Investigated by: Japanese Industrial Standards Committee

Standards Board

Technical Committee on Testing and Measurement Technology

JIS Z 4511 : 2005, First English edition published in 2006-04

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

In the event of any doubts arising as to the contents, the original JIS is to be the final authority.

Contents

Page

Introduction 1

1 Scope 1

2 Normative references 1

3 Terms and definitions 1

4 System of calibration 5

5 Method to obtain the uncertainty of the calibration constant 9

6 Uncertainty of calibration 9
6.1 Uncertainty of reference calibration 9
6.2 Uncertainty of practical calibration 9

7 Reference instrument and irradiation equipment 9
7.1 Reference meter 9
7.2 Practical reference meter 10
7.3 Performance of irradiation equipment and other devices required for calibration 11

8 Reference calibration 12
8.1 Calibration method 12
8.2 Calibration range of reference calibration 12
8.3 Environmental conditions of reference calibration 13
8.4 Irradiation conditions of reference calibration 13

9 Practical calibration 13
9.1 Calibration method of an exposure or an air kerma practical meter 13
9.2 Calibration method of a dose-equivalent practical meter 14
9.3 Determination of an ICRU-sphere dose-equivalent (rate) standard 14
9.4 Calibration range of practical calibration 14
9.5 Environmental conditions of practical calibration 15
9.6 Irradiation conditions of practical calibration 15

10 Arrangement of irradiation equipment and a meter 15

11 Radiation quality of X-rays 18
11.1 Measuring method of the 1st and 2nd half-value layers 18
11.2 Filter 19
11.3 Method to obtain effective energy 19
11.4 Homogeneity factor 19
11.5 Quality index 19
11.6 Marking of radiation quality 19

12 Method to obtain the calibration constant of exposure (rate), air kerma (rate) or air absorbed dose (rate) meter 19
12.1 In the case of substitution method 19
12.2 In the case of radiation-source method 20
12.3 In the case of inverse square law 20
13 Method to obtain the calibration constant of dose-equivalent (rate) meter 21
13.1 In the case of substitution method 21
13.2 In the case of radiation-source method 21
13.3 In the case of inverse square law 22
14 Record of calibration result 23
Annex 1 (normative) Calibration method of personal dosemeter 27
Annex 2 (normative) Calibration for confirmation of practical meter 34

Methods of calibration for exposure meters, air kerma meters, air absorbed dose meters and dose-equivalent meters

Introduction This Japanese Industrial Standard revises **JIS Z 4511:1999** completely including the amendment added in the fiscal year of 2000. The revision responds to enforcement of the new radiation hazard prevention related statute which incorporates the new Measurement Law effective as of April, 2001 and **ICRP-1990** recommendation. The revision introduces an air kerma standard and concerns the fundamental matters of the system of calibration.

1 Scope This Standard specifies the calibration method (however, excluding the calibration based on the Measurement Law by a specified standard instrument or a specified secondary standard instrument, etc.) of an exposure meter, an air kerma meter, an air absorbed dose meter, and a dose-equivalent meter of photon energy 10 keV to 3 MeV (hereafter referred to as "meters").

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. If the indication of the year of publication is given to these referred standards, only the edition of the indicated year constitutes the provision of this Standard but the revision and supplement made thereafter do not apply. The normative references without the indication of the year of coming into effect apply only to the most recent editions (including amendments).

JIS Z 4001 *Glossary of terms used in nuclear energy*

JIS Z 4331 *Calibration phantom for X-, γ- and β-ray personal dosemeters*

JIS Z 8103 *Glossary of terms used in measurement*

JIS Z 8401 *Guide to the rounding of numbers*

ISO 4037-1:1996 *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy— Part 1: Radiation characteristics and production methods*

ISO 4037-3:1999 *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy— Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

3 Terms and definitions For the purposes of this Standard, the definitions given in **JIS Z 4001** and **JIS Z 8103** and the following definitions apply.

Remarks 1 The dose equivalent per unit time is called "dose equivalent rate", and the dose equivalent (or dose equivalent rate) is expressed with "the dose equivalent (rate)" in this Standard.

2 The exposure per unit time is called "exposure rate", and an exposure (or exposure rate) is expressed with "an exposure (rate)" in this Standard. Similarly, an air kerma and air absorbed dose per unit time are called "the rate of an air kerma", and "rate of an air absorbed dose", respectively. In this Standard, an air kerma (or rate of an air kerma) is expressed with an air kerma (rate), and an air absorbed dose (or rate of an air absorbed dose) is expressed with an air absorbed dose (rate).

a) **Dose-equivalent-related terms and definitions**

1) **ICRU sphere** a sphere where mass percentage is elemental composition of oxygen 76.2 %, carbon 11 .1 %, hydrogen 10.1 %, and nitrogen 2.6 %, the density is 1 g/cm^3 and the diameter is 30 cm

2) **ICRU slab** a rectangular parallelepiped where mass percentage is elemental composition of oxygen 76.2 %, carbon 11 .1 %, hydrogen 10.1 %, and nitrogen 2.6 %, the density is 1 g/cm^3 and the dimension is 30 cm × 30 cm × 15 cm

3) **1 cm dose equivalent** generic name of 1 cm dose equivalent in connection with a place, and 1 cm dose equivalent in connection with an individual

1 cm dose equivalent in connection with a place is the dose equivalent at the depth of 1 cm from an entrance plane on the principal-axis along the direction of incidence, when an **ICRU** sphere is irradiated with the photon of the plane parallel beam of the single direction. Moreover, 1 cm dose equivalent in connection with an individual is the dose equivalent at the depth of 1 cm from an entrance plane on the principal axis, when **ICRU** slab is irradiated at right angles to a principal plane with the photon of the plane parallel beam of the single direction. 1 cm dose equivlalent is indicated by H_{1cm}.

In addition, this dose equivalent rate is indicated by $\dot{H}_{1cm}$.

4) **70 μ m dose equivalent** generic name of 70 μ m dose equivalent in connection with a place, and 70 μ m dose equivalent in connection with an individual

70 μ m dose equivalent in connection with a place is the dose equivalent in the depth of 70 μ m from an entrance plane on the principal-axis along the direction of incidence, when an **ICRU** sphere is irradiated with the photon of the plane parallel beam of the single direction. Moreover, 70 μ m dose equivalent in connection with an individual is the dose equivalent in the depth of 70 μ m from an entrance plane on the principal axis, when **ICRU** slab is irradiated at right angles to a principal plane with the photon of the plane parallel beam of the single direction. The 70 μ m dose equivalent is indicated by $H_{70\mu m}$.

In addition, this dose equivalent rate is indicated by $\dot{H}_{70\mu m}$.

5) **ICRU-sphere dose equivalent (rate)** generic name of 1 cm dose equivalent (rate) and 70 μm dose equivalent (rate) in connection with a place

6) **ICRU slab dose equivalent (rate)** generic name of 1 cm dose equivalent (rate) and 70 μm dose equivalent (rate) in connection with an individual

7) **dose-equivalent conversion factor** conversion factor used when computing the ICRU-sphere dose equivalent (rate) or the ICRU slab dose equivalent (rate) from an air kerma (rate) in the free space

8) **air absorbed dose conversion factor** conversion factor used when computing an air absorbed dose (rate) from an exposure (rate) (= 33.97 Gy × kg/C)

9) **air kerma conversion factor** conversion factor used when computing an air kerma (rate) from an exposure (rate) ($=33.97 \times (1-g)^{1}$ Gy × kg/C). Here, g shows the loss rate by bremsstrahlung

b) Calibration-related terms and definitions

1) **exposure meter** meter for measuring an exposure (rate)

2) **air kerma meter** meter for measuring an air kerma (rate)

3) **air absorbed dose meter** meter for measuring an air absorbed dose (rate)

Hereafter, in this Standard, for the photon not exceeding 1.5 MeV, an air absorbed dose meter is included in an air kerma meter.

4) **dose-equivalent meter** meter for performing measurement of an ICRU-sphere or the ICRU slab dose equivalent (rate)

5) **exposure (rate) standard** exposure (rate) used as the standard which is set up by the calibrating apparatus

6) **air kerma (rate) standard** air kerma (rate) used as the standard which is obtained by multiplying an exposure (rate) standard by an air kerma conversion factor

7) **air absorbed dose (rate) standard** air absorbed dose (rate) standard used as the standard which is obtained by multiplying an exposure (rate) standard by an air absorbed dose conversion factor

Hereafter, in this Standard, an air absorbed dose (rate) standard is included in an air kerma (rate) standard.

8) **dose-equivalent (rate) standard** the ICRU-sphere dose equivalent (rate) or the ICRU slab dose equivalent (rate) used as the standard which is obtained by multiplying an air kerma (rate) standard by a dose-equivalent conversion factor

9) **dose (rate) standard** generic name of an exposure (rate) standard, an air kerma (rate) standard, an air absorbed dose (rate) standard, and a dose-equivalent (rate) standard

10) **calibration** to find a relation between a dose (rate) standard and a value indicated by a meter

11) **calibrating apparatus** a reference instrument, irradiation equipment, or γ-ray source used as a standard for setting up an exposure (rate) or an air kerma (rate) standard

12) **specified standard instrument** standard meter which the Minister of Economy, Trade and Industry specified based on the Measurement Law

13) **specified secondary standard instrument** standard instrument which are calibrated by using a specified standard instrument based on the Measurement Law

Moreover, in this Standard, this category includes the standard instrument (working standard) which is deemed to be equivalent to a specified secondary standard instrument based on the Measurement Law.

14) **reference instrument** meter which serves as a standard when calibration is carried out

In the class of reference instrument, there are a reference meter and a practical reference meter. Moreover, in the class of practical reference meter, there are an exposure or an air kerma practical reference meter, and a dose-equivalent practical reference meter.

15) **irradiation equipment** generic name of the γ-ray irradiation equipment or X-ray irradiation equipment which are used for calibration

16) **reference γ-ray source** a γ-ray source used as the standard for setting up a dose (rate) standard, whose value is decided by a specified secondary standard instrument

17) **practical γ-ray source** a γ-ray source used only in order to calibrate a practical meter

There are a practical standard γ-ray source whose dose rate was decided by the reference meter, and a γ-ray source without a dose-rate standard for calibration for confirmation.

18) **practical irradiation equipment** simple irradiation equipment for setting up a dose (rate) standard

19) **practical meter** meter which is in practical use

There are an exposure practical meter, an air kerma practical meter, an air absorbed dose practical meter, and a dose-equivalent practical meter. In this Standard, an air absorbed dose practical meter is included in an air kerma practical meter.

20) **reference calibration** calibration of a specified secondary reference instrument, a reference meter, or a practical reference meter

21) **practical calibration** calibration of a practical meter

22) **confirmation calibration** simple calibration performed about the practical meter which is in practical use, without using a dose (rate) standard and with paying attention to whether the calibration constant varies or not due to a practical radiation source, whose purpose is to confirm periodical performance maintenance

23) **substitution method** method to calibrate by placing alternately a reference instrument and a meter to be calibrated in the irradiation field of the same condition

Here, the substitution method includes the two methods. One is that a meter to be calibrated and a reference instrument specified in **ISO 4037-3** are simultaneously irradiated. The other is that the beam monitor which monitors the output change of irradiation equipment is concurrently used.

24) **radiation-source method** method to calibrate a meter to be calibrated by using a reference γ -ray source or a practical reference γ -ray source

25) **inverse square law** method to calculate the exposure, the air kerma, or the dose equivalent (rate) at an arbitrary distance based on a dose (rate) standard, and to calibrate a meter to be calibrated

26) **calibration constant** value obtained by dividing the exposure (rate), the air kerma (rate), or the dose equivalent (rate) specified as a standard by the indicated value of a meter to be calibrated

4 **System of calibration** The system of calibration which is traceable from a national standard to primary, secondary and a practical exposure (rate), or an air kerma (rate) standard is specified in figure 1 and the following:

a) Calibration is classified into the reference calibration for a specified secondary standard instrument, a reference meter, or a practical reference meter, and the practical calibration for a practical meter.

b) Reference calibration consists of calibration by the primary exposure (rate) or the primary air kerma (rate) standard of a specified secondary standard instrument, calibration by the secondary exposure (rate) or the secondary air kerma (rate) standard of a reference meter, and calibration by the practical exposure (rate), the practical air kerma (rate) or the practical dose-equivalent (rate) standard of a practical reference meter.

c) Practical calibration consists of the calibration of an exposure practical meter and an air kerma practical meter by the practical exposure (rate) standard and the practical air kerma (rate) standard, respectively, as well as the calibration for confirmation. Calibration of a dose-equivalent practical meter shall be based on the dose-equivalent (rate) standard which is obtained by multiplying the practical air kerma (rate) standard by the dose-equivalent conversion factor. It shall also be based on the practical dose-equivalent (rate) standard whose value is decided by the practical dose-equivalent (rate) standard, as well as the calibration for confirmation.

d) A specified standard instrument is a national standard instrument of the highest class in the Measurement Law. A specified secondary standard instrument is a standard meter which is calibrated by the primary exposure (rate) standard or the primary air kerma (rate) standard.

e) A reference γ-ray source is a γ-ray source where a specified secondary standard instrument determines the value of the exposure rate, the rate of an air kerma, or the dose equivalent rate of a radiation source. When γ-ray irradiation equipment with the similar value setting is used independently, it shall be included in this category.

f) A practical reference γ-ray source is a γ-ray source where a reference meter determines the value of the exposure rate, the rate of an air kerma, or the dose equivalent rate of a radiation source. When γ-ray irradiation equipment with the similar value setting is used independently, it shall be included in this category.

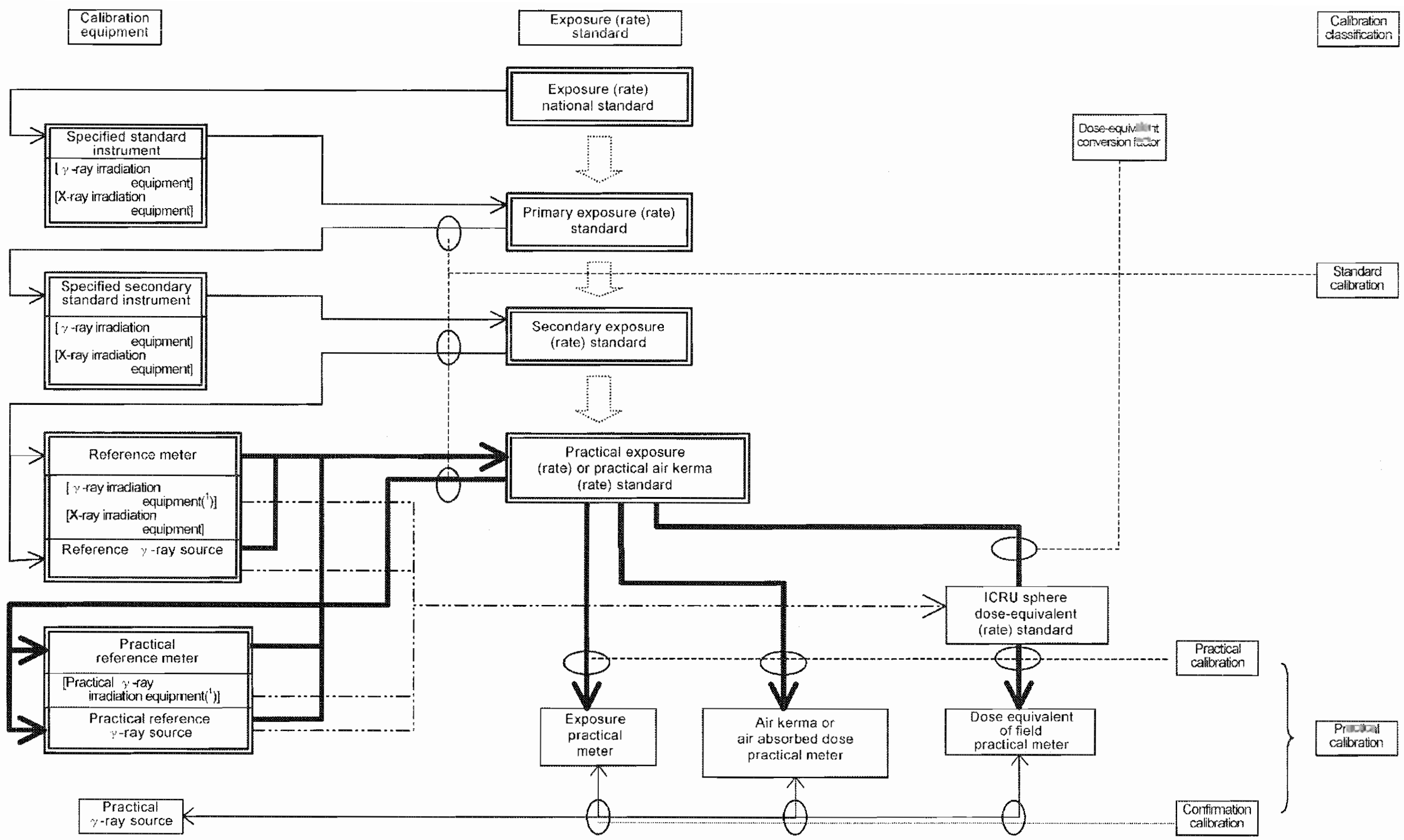


Figure 1 System of calibration

Note (1) The air kerma (rate) of a collimate type γ-ray irradiation equipment or a reference γ-ray source is multiplied by a dose-equivalent conversion factor, and it can be used as the irradiation equipment or the reference γ-ray source of the **ICRU**-sphere dose equivalent (rate). Practical γ-ray irradiation equipment is assigned a value by the **ICRU**-sphere dose equivalent (rate), and it can set a practical **ICRU**-sphere dose-equivalent (rate) standard.

Remarks 1 Calibration of a specified secondary standard instrument and a reference meter (including a working reference standard) is outside the scope of this Standard. Moreover, the method of confirmation calibration is shown in Annex 2.

2 A solid line shows actual relation and the arrow of a dotted line shows relation of between a national standard and reference standard. A long dashed double-short dashed line shows the relation to a practical **ICRU**-sphere dose-equivalent (rate) standard.

3 The system of the calibration by an **ICRU** slab dose-equivalent (rate) standard is shown in Annex 1 attached figure 1.

Reference : An exposure (rate) standard is multiplied by an air kerma conversion factor, and it can be used as an air kerma (rate) standard. Moreover, the practical exposure (rate) standard is multiplied by the air absorbed dose conversion factor in order to set up the filed of the practical air absorbed dose (rate) standard. In such a field, an air absorbed dose practical meter can be calibrated.

Figure 1 (concluded)

5 Method to obtain the uncertainty of the calibration constant The reliability in the uncertainty of the calibration constant shall be 95 %. Synthesis of uncertainty shall be the square root of the sum of square of the uncertainty related to each event. The uncertainty in calibration shall be found the square root of the sum of the square of uncertainty of the field where a standard was set (uncertainty of the calibration including the performance of a reference meter, or uncertainty of calibration of a reference γ-ray source) and the sum of the square of uncertainty of a meter to be calibrated (including uncertainty of calibration).

6 Uncertainty of calibration

6.1 Uncertainty of reference calibration The uncertainty of reference calibration shall be specified as follows:

a) In the field where the γ-ray energy of ^{137}Cs or ^{60}Co was used to set the practical exposure (rate) standard or the practical air kerma (rate) standard, when an exposure or an air kerma practical reference meter is to be calibrated, its uncertainty shall be 6 % or under.

b) In the field where the γ-ray energy of ^{137}Cs or ^{60}Co was used to set the dose-equivalent (rate) standard, when a dose-equivalent practical reference meter is to be calibrated, its uncertainty shall be 6 % or under.

Information : In the field where the secondary exposure (rate) standard or the secondary air kerma (rate) standard was set, when a reference meter is to be calibrated, its uncertainty shall be 5 % or under.

6.2 Uncertainty of practical calibration The uncertainty of practical calibration shall be specified as follows:

a) In the field where the practical exposure (rate) standard or the practical air kerma (rate) standard was set, when an exposure or an air kerma practical meter is to be calibrated, its uncertainty shall be 20 % or under.

b) In the field where the practical air kerma (rate) standard was multiplied by the dose-equivalent conversion factor, and the dose-equivalent (rate) standard was set, when a dose-equivalent practical meter is to be calibrated, its uncertainty shall be 20 % or under.

In addition, the error of the dose-equivalent conversion factor for finding a dose-equivalent (rate) standard shall not be considered.

7 Reference instrument and irradiation equipment

7.1 Reference meter The detector of a reference meter shall be an ionization-chamber type. The ionization chamber shall have the wall thickness or entrance window thickness and meet the performance indicated in table 1, depending on each energy range used.

Table 1 Performance of a reference meter (%)

Performance item	Range of energy used by a detector		
	10 keV or over to and excluding 30 keV	30 keV or over to and excluding 300 keV	300 keV or over to and excluding 3000 keV
Reproducibility of response (2)	< 1.0	< 1.0	< 1.0
Directional characteristics (3)	< 1.0	< 0.5	< 0.5
Dose-rate characteristics (4)	< 0.5	< 0.5	< 0.5
Stem effect (5)	< 0.5	< 1.0	< 0.5
Linearity of the scale (6)	< 0.5	< 0.5	< 0.5
Energy response (7)	< ± 10	< ± 6	< ± 2

Notes (2) While the irradiation conditions such as the radiation quality and dose rate are kept almost constant, if irradiation lasts for a long time or if irradiation is performed on different days, then the calibration constant changes. Calculate the reproducibility of response from the calibration constant. Subtract its minimum from its maximum and divide the difference by its minimum. Express the quotient in percentage.

(3) If irradiation is performed with different incident directions within the range of ± 2° of the specified direction, then the indicated value changes. Calculate the directional characteristic from the indicated value. Subtract its minimum from its maximum and divide the difference by its minimum. Express the quotient in percentage.

(4) If an exposure or an air kerma meter is irradiated by the rated dose or the working maximum dose or about 1/2 dose rate, then the calibration constant changes. Calculate the dose-rate characteristic by dividing the difference of calibration constant by its minimum. Express the quotient in percentage.

(5) The indicated value differs depending on whether or not a shield is available for the handle of ionization chamber (including a preamplifier). Calculate the stem effect by dividing the difference of indicated value by the value obtained without the shield. Express the quotient in percentage.

(6) Within the same measurement range, the calibration constant differs in the indication range of 30 % to 100 % of maximum scale value. Calculate the linearity of scale from the calibration constant. Subtract its minimum from its maximum and divide the difference by its minimum. Express the quotient in percentage.

(7) Calculate the energy response C_E (%) by the following formula:

$$C_{\mathrm{E}} = \pm \frac{N_{\mathrm{max}} - N_{\mathrm{min}}}{N_{\mathrm{max}} + N_{\mathrm{min}}} \times 100$$

Where, N_{max}: maximum calibration constant in the range of energy used by a detector

N_{min}: minimum calibration constant in the range of energy used by a detector

7.2 Practical reference meter A practical reference meter shall be specified as follows:

a) A detector of practical reference meters shall be the same type detector of the following meters: the meters which have the performance equivalent to a reference meter; and the particular exposure or air kerma practical meter or the dose-equivalent practical meter which is to be subjected to practical calibration.

b) The performance of a practical reference meter shall be indicated by a coefficient of variation. When a practical reference meter is irradiated 4 times or more on the same irradiation conditions with the γ-ray irradiation equipment of ^{137}Cs or ^{60}Co, the coefficient of variation of a meter indicated value shall be 0.03 or under.

7.3 Performance of irradiation equipment and other devices required for calibration
The performance of irradiation equipment and other devices required for calibration shall be specified as follows:

a) The performance of irradiation equipment used to set up the field for exposure (rate) or air kerma (rate) standard, and other devices required for calibration shall be as specified in table 2.

Table 2 Performance of irradiation equipment and other devices required for calibration

Equipment	Item	Tolerance
γ-ray irradiation equipment	Exposure field homogeneity % (8)	± 2
	Shutter opening-and-closing speed % (9)	1 or under
	Reproducibility (10)	0.005
X-ray irradiation equipment	Exposure field homogeneity % (8)	± 3
	Shutter opening-and-closing speed % (9)	One or less
	X-ray-output stability % (11)	± 2
Thermometer	Instrumental error ℃	± 1
Hygrometer	Instrumental error %	± 5
Manometer	Instrumental error kPa	± 0.4
Timer	Instrumental error %	± 0.1
Length meter	Instrumental error %	± 0.1

Notes (8) The homogeneity of the exposure field of γ-ray irradiation equipment and X-ray irradiation equipment means the homogeneity of the exposure (rate) or an air kerma (rate) in the exposure field, when one meter to be calibrated is irradiated and when multiple meters are simultaneously irradiated.

(9) Shutter opening-and-closing speed indicates the percentage of the shutter opening-and-closing time to the irradiation time.

(10) The reproducibility of γ-ray irradiation equipment is the coefficient of variation of indicated values when a reference meter is irradiated 10 times by changing a radiation source from a storing state to an irradiation state.

(11) When the system is provided with a monitor ionization chamber which monitors X-ray-output change, the stability shall be ± 5 % and shall compensate fluctuations.

b) The combined performance of a practical irradiation equipment and a practical reference meter shall be indicated by the coefficient of variation of an indicated value when a practical irradiation equipment irradiates a practical reference meter 4 times or more under the identical conditions. The coefficient of variation shall be 0.05 or under.

8 Reference calibration

8.1 Calibration method

8.1.1 A practical reference meter or practical reference γ-ray source A practical reference meter or a practical reference γ-ray source shall be calibrated by one method of the following:

a) A substitution method shall be used in the field where a practical exposure (rate) standard or the practical air kerma (rate) standard was set by a reference meter and γ-ray irradiation equipment.

b) A radiation-source method shall be used in the field where a practical exposure (rate) standard or the practical air kerma (rate) standard was set by a reference γ-ray source.

c) Determination of value of the dose rate of a practical reference γ-ray source shall be performed by using a reference meter at the specified distance from a radiation source.

8.2 Calibration range of reference calibration

8.2.1 Practical use reference meter The calibration range of a practical reference meter shall be as specified in table 3.

Table 3 The calibration range of a practical reference meter

Type of meter	Scale	Energy
Digital type	One point near the centre of each decade in a required mesurement range	— As for a practical reference meter, one point of 662 keV (^{137}Cs) or 1 250 keV (^{60}Co).
Analog type	One point of 1/2 or more of maximum scale of each measurement range in a required mesurement range	

Information : The calibration range of a reference meter is shown in informative table 1.

Informative Table 1 The calibration range of a reference meter

Type of meter	Scale	Energy
Digital type	One point near the centre of each decade in a required measurement range	— As for 10 keV or over to and excluding 30 keV, one or more points near 10 keV, 20 keV, and 30 keV. — As for 30 keV or over to and excluding 300 keV, two or more points near 30 keV, 50 keV, 80 keV, 150 keV, and 200 keV. — As for 300 keV or over to and excluding 3 000 keV, two points at 662 keV (^{137}Cs) and 1 250 keV (^{60}Co).
Analog type	One point of 1/2 or more of maximum scale of each measurement range in a required measurement range	

8.3 Environmental conditions of reference calibration The environmental conditions for performing reference calibration shall be specified in table 4.

Table 4 Environmental conditions at the time of reference calibration

Item	Conditions
Ambient air temperature ℃	20 ± 5
Relative humidity %	≦ 85
Atmospheric pressure kPa	95.0 to 103.0
Background air kerma rate μ Gy/h	In the domain where a meter is calibrated, ≦ 0.22.

8.4 Irradiation conditions of reference calibration

8.4.1 Practical reference meter The irradiation conditions in the case of calibration of a practical reference meter shall satisfy the uncertainty specified to **6.1.a)** or **6.1.b)**.

9 Practical calibration

9.1 Calibration method of an exposure or an air kerma practical meter Calibration of an exposure or an air kerma practical meter shall be performed by one method of the following:

a) In the field where a reference meter and irradiation equipment set the practical exposure (rate) standard or the practical air kerma (rate) standard, a substitution method or an inverse square law shall be used.

b) In the field where a practical reference meter and practical irradiation equipment set the practical exposure (rate) standard or the practical air kerma (rate) standard, a substitution method or an inverse square law shall be used.

c) In the field where a reference γ-ray source or a practical standard γ-ray source set the practical exposure (rate) standard or the practical air kerma (rate) standard, a radiation-source method or an inverse square law shall be used.

9.2 Calibration method of a dose-equivalent practical meter Calibration of an ICRU-sphere dose-equivalent practical meter shall be by one method of the following:

a) In the field where a reference meter and irradiation equipment determines the practical air kerma (rate) standard, which is multiplied by the dose-equivalent conversion factor in order to set the **ICRU**-sphere dose-equivalent (rate) standard, a substitution method or an inverse square law shall be used.

b) An **ICRU**-sphere dose-equivalent practical meter and the meter having the same type detector as this shall be calibrated by the **ICRU**-sphere dose-equivalent (rate) standard which was set by **a)**. By using this, value determination of practical irradiation equipment shall be performed by an **ICRU**-sphere dose equivalent rate. Then, an **ICRU**-sphere dose-equivalent practical meter shall be calibrated by a substitution method.

c) In the field where a reference γ-ray source or a practical reference γ-ray source shall determine the air kerma (rate) standard, which shall be multiplied by the dose-equivalent conversion factor in order to set the **ICRU**-sphere dose-equivalent (rate) standard, a radiation-source method or an inverse square law shall be used.

9.3 Determination of an ICRU-sphere dose-equivalent (rate) standard The **ICRU**-sphere dose equivalent (rate) is computed by the following method using a practical air kerma (rate) standard.

a) H_{1cm} shall be computed by using a practical air kerma (rate) standard (K) and 1 cm dose-equivalent conversion factor (f_{1cm}) which is indicated in attached table 1, and by the following formula.

$$H_{1cm} = K \times f_{1cm}$$

b) $H_{70\mu m}$ shall be computed by using a practical air kerma (rate) standard (K) and 70 μm dose-equivalent conversion factor ($f_{70\mu m}$) which is indicated in attached table 2, and by the following formula.

$$H_{70\mu m} = K \times f_{70\mu m}$$

9.4 Calibration range of practical calibration The calibration range of a practical meter shall be as specified in table 5.

Table 5 The calibration range of a practical meter

Type of meter	Calibration range
Digital type	One point near the centre of each decade.
Analog type	— In the case of a linear scale, one point of 1/2 or more of the maximum scale for each measuring range. — In the case of the logarithmic scale, one point near two scales for each decade.
Totalizing type	One point within the entire measuring range.

Remarks : If a meter has two or more measuring ranges and the range to be used is limited, then the maximum range to ensure performance which conforms to requirement for use may be specified as the upper limit.

9.5 Environmental conditions of practical calibration The environmental conditions which perform practical calibration shall be as specified in table 6.

Table 6 Environmental conditions at the time of calibration of practical calibration

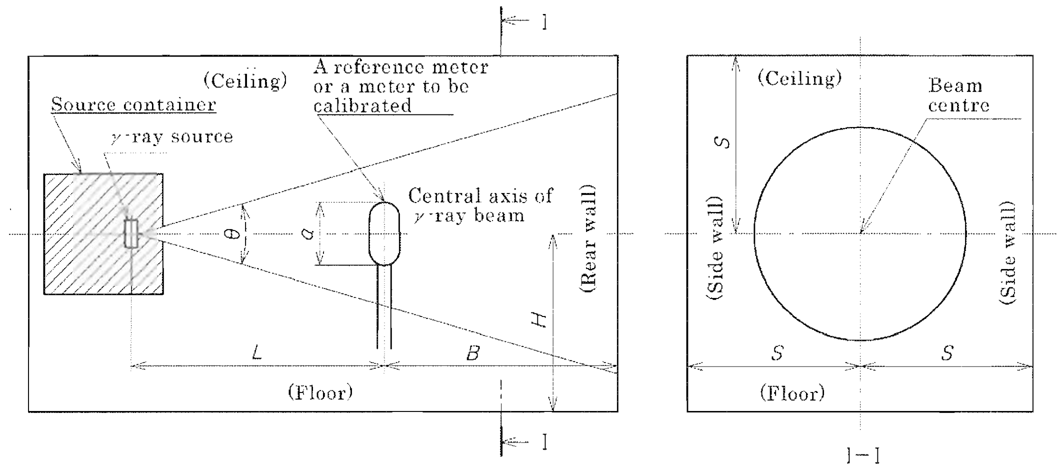
Item	Conditions
Ambient air temperature ℃	20 ± 10
Relative humidity %	≦ 85
Atmospheric pressure kPa	85.0 to 106.0
Rate of background air kerma μ Gy/h	In the domain where a meter is calibrated, ≦ 0.22.

9.6 Irradiation conditions of practical calibration The irradiation conditions in the case of performing practical calibration shall satisfy the uncertainty specified in **6.2**.

10 Arrangement of irradiation equipment and a meter The concrete geometric arrangement of the irradiation equipment and a meter in reference calibration shall be specified as follows:

a) γ -irradiation equipment shall be specified as follows:

1) In the case of a collimate γ -ray, it shall be as specified in figure 2.



L: Distance between radiation source and meter

a: Dimension of detector of meter

B: Distance between meter and rear wall

H: Distance between central axis of beam and floor

S: Distance between central axis of beam and side wall (including ceiling)

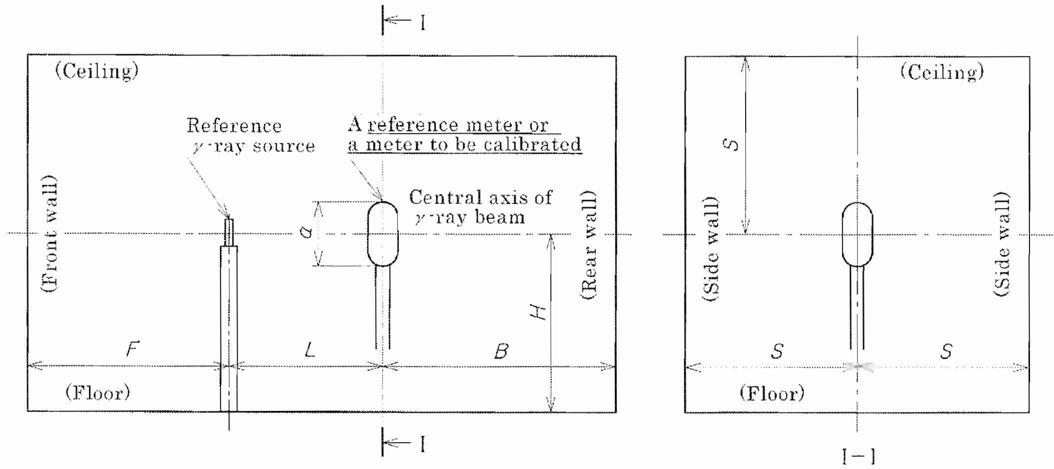
θ: Spread angle of beam

L (m)	*a/L*	*B* (m)		*H* (m)	*S* (m)	θ (degree)
		L ≦ 3	3 < *L*			
0.5 or more	1/5 or less	1.0 or more	L/3 or more	1.2 or more	1.5 or more	30 or less

Remarks : The spread angle (θ) of the beam shall be 40 degrees at maximum. In this case, at the time of $L \leqq 3$, *B* shall be 1.5 (m) or over. At the time of $L > 3$, it shall be $L/2$ (m) or over.

Figure 2 In the case of a collimate γ-ray

2) In the case of a non-collimate γ-ray, it shall be as specified in figure 3.



L: Distance between radiation source and meter

a: Dimension of detector of meter

B: Distance between meter and rear wall

H: Distance between central axis of beam and floor

S: Distance between central axis of beam and side wall (including ceiling)

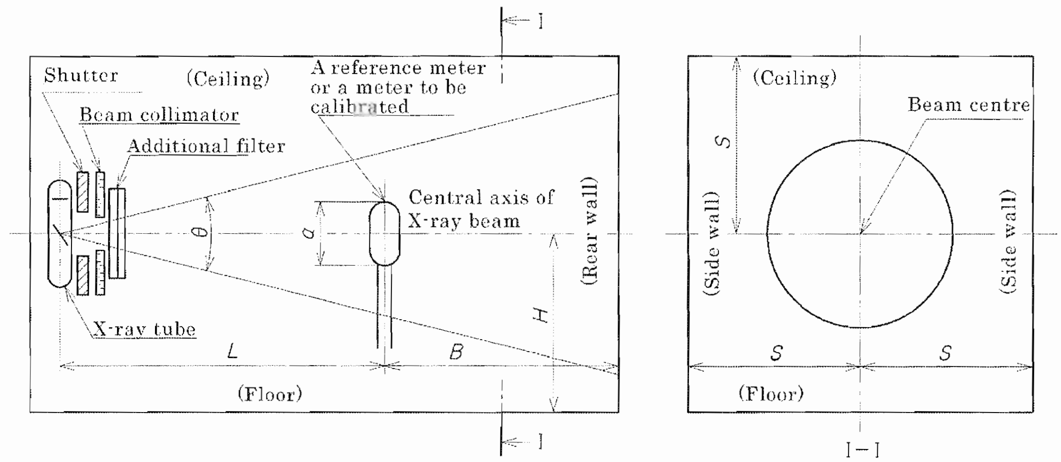
F: Distance between radiation source and front wall

a/L	*L* (m)	*B* (m)	*S* (m)	*F* (m)	*H* (m)
1/5 or less	2 or less	2 or more	2 or more	2 or more	1.2 or more

Remarks : When the effect of scattered radiation can be evaluated, the distance (*F*) between a radiation source and a front wall may be 1 m.

Figure 3 In the case of a non-collimate γ-ray

b) X-ray irradiation equipment shall be as specified in figure 4.



L: Distance between radiation source and meter

a: Dimension of detector of meter

B: Distance between meter and rear wall

H: Distance between central axis of beam and floor

S: Distance between central axis of beam and side wall (including ceiling)

θ : Spread angle of beam

L (m)	a/L	B (m)	H (m)	S (m)	θ (degree)
1.0 or more, 6.0 or less	1/10 or less	2.0 or more	1.2 or more	1.5 or more	15 or less

Remarks : A beam collimator and an added filter shall be placed as close as possible to an X-ray tube in order to reduce the effect of scattered radiation.

Figure 4 In the case of X-ray irradiation

11 Radiation quality of X-rays

11.1 Measuring method of the 1st and 2nd half-value layers Under a certain tube voltage, tube current, the characteristic filter (including the air space), and added-filter conditions, a dose rate over the thickness of the filter for half-value-layer measurement of a certain single substance shall be measured. Then, an attenuation-factor curve shall be created. Thickness of the filter for measurement corresponding to attenuation factors 1/2 and 1/4 shall be t_1 and t_2, which is obtained as follows:

The 1st half-value layer = t_1, the 2nd half-value-layer = $(t_2 - t_1)$

In addition, the detector of good energy responce shall be used. The filter shall be set perpendicularly to an X-ray-beam axis. A narrow beam shall be used for measurement under the condition where contribution of the scattered radiation from the filter, etc. is negligible.

11.2 Filter An added filter shall be set up near the radiation aperture of the X-ray tube. The substance used as a filter shall be of four kinds: aluminum, copper, tin, and lead.

The filter for half-value-layer measurement shall be of three kinds: aluminum, copper, and tin. The following substances shall be used as a filter, respectively: aluminum for the effective energy range of 40 keV, copper for the range of 30 keV to 200 keV, and tin for the range 0.1 MeV to 1 MeV.

As for the quality of the material of the substance used for the filter, the purity shall be 99.8 % or over, and 99 % or over for copper, tin, and lead, respectively. The uncertainty of thickness shall be 1 %.

11.3 Method to obtain effective energy The 1st half-value layer to the special material of a certain X-ray beam is set to t_1. It is necessary to obtain the photon-energy E where the photon attenuation coefficient of this substance becomes equal to $\ln 2/t_1$. This energy E shall be the effective-energy E_{eff} of those X-ray beams.

11.4 Homogeneity factor A homogeneity factor HC shall be obtained by the following formula.

$$HC = \frac{t_1}{(t_2 - t_1)}$$

11.5 Quality index A quality index QI shall be obtained by the following formula.

$$QI = \frac{E_{\mathrm{eff}}}{E_{\mathrm{max}}}$$

Where E_{eff}: effective energy

E_{max}: maximum energy (maximum energy of an X-ray spectrum corresponding to tube voltage)

11.6 Marking of radiation quality The radiation quality of X-rays is expressed with effective energy (keV or MeV). A half-value layer, a homogeneity factor, or a quality index shall be expressed together. Moreover, for the radiation quality of X-rays, it is allowed to use the radiation quality notation specified by **ISO 4037-1**. In this case, it is necessary to express together the tube voltage, average energy (keV or MeV) and a half-value layer and a homogeneity factor.

12 Method to obtain the calibration constant of exposure (rate), air kerma (rate), or air absorbed dose (rate) meter

12.1 In the case of substitution method It applies to the case where irradiation equipment calibrates a meter. The calibration constant of a meter to be calibrated shall be obtained by the following formula.

$$N = N_s \times \frac{Q_s}{Q}$$

Where N: the calibration constant of a meter to be calibrated

N_s: the calibration constant of a reference meter

Q_s: the net indicated value of a reference meter

Q: the net indicated value of a meter to be calibrated

12.2 In the case of radiation-source method It applies to the case where a reference γ-ray source or a practical reference γ-ray source calibrates a meter. The calibration constant of a meter to be calibrated shall be obtained by the following formula.

$$N = \frac{\dot{M}_s}{Q} \text{ (in the case of a dose-rate meter)}$$

or $$N = \frac{\dot{M}_s \times t}{Q} \text{ (in the case of a dose meter)}$$

Where N: the calibration constant of a meter to be calibrated

$\dot{M}_s$: the dose rate of a reference γ-ray source or a practical reference γ-ray source

Q: the net indicated value of a meter to be calibrated

t: irradiation time

12.3 In the case of inverse square law It applies to the case where γ-ray irradiation equipment, a reference γ-ray source, or a practical reference γ-ray source calibrates a meter. The calibration constant of a meter to be calibrated shall be obtained by the following formula.

$$N = \frac{\dot{M}_s}{Q} \text{ (in the case of a dose-rate meter)}$$

or $$N = \frac{\dot{M}_s \times t}{Q} \text{ (in the case of a dose meter)}$$

Where N: the calibration constant of a meter to be calibrated

Q: the net indicated value of a meter to be calibrated

t: irradiation time

$\dot{M}_s$: a dose rate by a γ-ray source, which is obtained by the following formula

$$\dot{M}_s = \dot{M}_l \times \frac{l^2}{L^2}$$

Where $\dot{M}_l$: the dose-rate standard at the distance of l from a γ -ray source

l : distance from a radiation source to a reference instrument when the value of $\dot{M}_l$ is determined

L : distance from a γ -ray source to a meter to be calibrated

However, when $\dot{M}_S$ is calculated at the distance L from a γ -ray source to a meter to be calibrated, it is necessary to use a dose-rate standard $\dot{M}_l$ at the distance of l which is close to L. The measurement interval of $\dot{M}_l$ shall be 1 m for collimate γ -ray, and 0.5 m for non-collimate γ -ray. Moreover, calculation formula of $\dot{M}_S$ may use a function formula of the measured $\dot{M}_l$ and the distance.

13 Method to obtain the calibration constant of dose-equivalent (rate) meter

13.1 In the case of substitution method It applies to the case where irradiation equipment calibrates a meter. The calibration constant of a meter to be calibrated shall be obtained by the following formula.

$$N' = \frac{H_s}{Q}$$

Provided that, $H_s = N_s \times f \times Q_s$

Where N' : the calibration constant of a meter to be calibrated

H_s : the ICRU-sphere dose equivalent corresponding to each depth

N_s : the calibration constant of a reference meter

f : the dose-equivalent conversion factor indicated in the attached table 1 and the attached table 2

Q_s : the net indicated dose of a reference meter

Q : the net dose-equivalent indicated value of a meter to be calibrated

13.2 In the case of radiation-source method It applies to the case where a reference γ -ray source or a practical reference γ -ray source calibrates a meter. The calibration constant of a meter to be calibrated shall be obtained by the following formula.

$$N' = \frac{\dot{H}_s}{Q} \text{ (in the case of a dose-equivalent-rate meter)}$$

$$\text{or } N' = \frac{\dot{H}_s \times t}{Q} \text{ (in the case of a dose-equivalent meter)}$$

provided that, $\dot{H}_s = \dot{K}_s \times f$

Where N': the calibration constant of a meter to be calibrated

H_s: an ICRU-sphere dose equivalent rate corresponding to each depth

$\dot{K}_s$: the air kerma rate of a reference γ-ray source or a practical reference γ-ray source

f: the dose-equivalent conversion factor indicated in attached table 1 and attached table 2

Q: the net dose-equivalent (rate) indicated value of a meter to be calibrated

t: irradiation time

13.3 In the case of inverse square law It applies to the case where γ-ray irradiation equipment, a reference γ-ray source, or a practical reference γ-ray source calibrates a meter. The value shall be obtained by the following formula.

$$N' = \frac{\dot{H}_s}{Q} \text{ (in the case of a dose-equivalent-rate meter)}$$

$$\text{or, } N' = \frac{\dot{H}_s \times t}{Q} \text{ (in the case of a dose-equivalent meter)}$$

provided that, $\dot{H}_s = \dot{K}_s \times f$

Where N': the calibration constant of a meter to be calibrated

$\dot{H}_s$: an ICRU-sphere dose equivalent rate corresponding to each depth

f: the dose-equivalent conversion factor indicated in attached table 1 and attached table 2

Q: the net dose-equivalent (rate) indicated value of a meter to be calibrated

t: irradiation time

$\dot{K}_s$: the an air kerma rate due to γ-ray source which is obtained by the method indicated in **12.3**

14 Record of calibration result The calibration result of a meter shall be described in the recording paper. The contents shall be as follows:

In addition, method to round numbers shall be as specified in **JIS Z 8401**.

a) In the case of a practical reference meter, the following shall be recorded: the result of calibration; the name, model, serial number, and manufacturer of the reference meter used and the meter to be calibrated; calibration method, environmental conditions, calibration date, name of calibration personnel; and other calibration conditions.

b) When a reference γ -ray source is used, the following shall be recorded: the radiation-source number, the nuclide, and a dose rate in a reference point. In addition, it shall be accompanied by the record which describes the following: name, model and serial number of a reference number used for value determination; personnel in charge of value determination; and date of calibration.

c) In the case of a practical meter, the following shall be recorded: the result of calibration; the name, model, and serial number of the meter to be calibrated; name of calibration personnel; and calibration date.

Attached Table 1 1 cm dose-equivalent conversion factor

(1 cm dose equivalent in connection with location)

X-rays and γ -ray energy (12) MeV	Conversion factor from air kerma to 1 cm dose equivalent (13) Sv/Gy
0.010	0.008
0.015	0.26
0.020	0.61
0.030	1.10
0.040	1.47
0.050	1.67
0.060	1.74
0.080	1.72
0.10	1.65
0.15	1.49
0.20	1.40
0.30	1.31
0.40	1.26
0.50	1.23
0.60	1.21
0.66(14)	1.20
0.80	1.19
1.0	1.17
1.25(15)	1.16
1.5	1.15
2.0	1.14
3.0	1.13
4.0	1.12
5.0	1.11
6.0	1.11
8.0	1.11
10	1.10

Notes (12) When the energies of the X-rays and γ -ray emitted from a radiation source are a single energy, it is the photon energy. When the said energies are not a single energy, it is the effective energy.

(13) It is a conversion factor from an air kerma to the **ICRU**-sphere dose equivalent in the depth of 1 cm.

(14) It is the energy of a ^{137}Cs γ -ray.

(15) It is the energy corresponding to the equivalent conversion factor of ^{60}Co γ -ray.

Information : This table was based on **ICRP Publ.74**.

Attached Table 2 70μm dose-equivalent conversion factor

(70μm dose equivalent in connection with location)

X-rays and γ -ray energy (12) MeV	Conversion factor from air kerma to 70μm dose equivalent (16) Sv/Gy
0.010	0.95
0.015	0.99
0.020	1.05
0.025	1.13
0.030	1.22
0.040	1.41
0.050	1.53
0.060	1.59
0.080	1.61
0.10	1.55
0.15	1.42
0.20	1.34
0.30	1.31
0.40	hereafter, the same as 1 cm dose equivalent
0.50	
0.60	
0.66(15)	
0.80	
1.0	
1.25(16)	
1.5	
2.0	
3.0	
4.0	
5.0	
6.0	
8.0	
10	

Notes (12) Note (14), and note (15) refer to note of attached table 1.

(16) It is a conversion factor from an air kerma to the **ICRU**-sphere dose equivalent of the depth of 70μm.

Information : This table was based on **ICRP Publ.74**.

Attached Table 3 Exposure−air kerma conversion factor

Energy of X-rays and γ-ray(17) MeV	Conversion factor from an exposure to an air kerma (18) mGy/R	1-g(19)
0.010	8.76	1.000
(In the range from 0.010 MeV to 1.0 MeV, it is the same as the conversion factor of 0.010 MeV)		
1.0	8.76	1.000
1.5	8.76	0.996
2.0	8.83	0.995
3.0	8.85	0.991
4.0		0.988
5.0		0.984
6.0		0.980
8.0		0.972
10		0.964

Notes (17) In the case of single energy, the energy of X-ray and γ-ray shall be photon energy. When they are not single energy, it shall be effective energy. If there is no corresponding energy, it shall be found by interpolation.

(18) It is a conversion factor from an exposure (unit: R) to an air kerma in free space. Here, 1 R = 2.58×10^{-4} C/kg. When energy is 3 MeV or over, deviation from electronic equilibrium makes it impossible to accurately determine an exposure.

(19) (1-g) is a correction coefficient due to bremsstrahlung loss.

Information : Source **ICRU 47** (1992)

Annex 1 (normative)
Calibration method of personal dosemeter

1 **Scope** This Annex specifies the calibration method of a personal dosemeter.

2 **System of personal dosemeter calibration** The system of personal dosemeter calibration is specified in clause 4 of the text, Annex 1 attached figure 1 and the following:

a) Calibration is classified into the phantom calibration where a reference personal dosemeter is installed in the phantom, and the calibration without the phantom.

b) Phantom calibration shall be calibration of the personal dosemeter by the **ICRU** slab dose-equivalent (rate) standard, which is obtained by multiplying the practical air kerma (rate) standard by the dose-equivalent conversion factor (hereafter referred to as "dose-equivalent conversion factors") indicated in Annex 1 attached table 1 and Annex 1 attached table 2.

c) The calibration without the phantom(1) shall be calibration of the personal dosemeter performed by the **ICRU** slab dose-equivalent (rate) standard which is set by a dose-equivalent practical reference meter and irradiation equipment or a γ -ray source.

Note (1) : The calibration of a personal dosemeter without the phantom is the method where a personal dosemeter is used as a dose-equivalent practical reference meter. It can be performed only when the dosemeter of the same type is calibrated.

3 **Phantom calibration** Phantom calibration of a personal dosemeter shall be specified as follows:

a) **The method of phantom calibration** Phantom calibration of a personal dosemeter shall be performed by installing a personal dosemeter in the phantom specified by **JIS Z 4331**. In this case, a personal dosemeter shall be placed at the central part of the phantom and as close as possible to the phantom.

Calibration of the personal dosemeter installed in the phantom (hereafter referred to as "phantom installed personal dosemeters") shall be performed by one method of the following:

1) In the field where a reference meter and irradiation equipment determines the practical air kerma (rate) standard, which is multiplied by the dose-equivalent conversion factor in order to set the **ICRU** slab dose-equivalent (rate) standard, a substitution method or an inverse square law shall be used.

2) In the field where a reference γ -ray source or a practical reference γ -ray source determines the practical air kerma (rate) standard, which is multiplied by the

dose-equivalent conversion factor in order to set the **ICRU** slab dose-equivalent (rate) standard, a radiation-source method or an inverse square law shall be used.

b) **Irradiation equipment and arrangement of a personal dosemeter** The concrete geometric arrangement of irradiation equipment and a phantom installed personal dosemeter shall be based on clause **10** of the text and the following:

1) The whole phantom where the personal dosemeter is installed shall be irradiated.

2) Distance between a radiation source and a phantom installed personal dosemeter shall be 2 m or over.

3) The calibration distance shall be usually measured between a radiation source centre and a detector centre.

4) The phantom shall be installed so that perpendicular at the centre of irradiation plane may align with the central axis of irradiation beam.

5) The phantom shall be installed on a wooden frame or a stand made of low density material, which is apart 20 cm or over from the calibration table surface.

Remarks 1 Because the calibration distance is 2 m or over, the calibration distance may be measured on the surface of the phantom.

2 When carrying out phantom calibration, a small table is used for supporting the phantom above the floor. It is referred to as "calibration tables".

c) **Method to obtain the calibration constant** The calibration constant of a personal dosemeter shall be obtained by the method specified in clause **13** of the text.

4 **Calibration without the phantom** The calibration without the phantom of a personal dosemeter shall be specified as follows:

a) The personal dosemeter calibrated by clause **3** [hereafter referred to as "reference personal dosemeters" (2)] shall be irradiated, without the phantom, using irradiation equipment or a γ-ray source, and the indicated value (I_0) shall be obtained. Next, suppose that the value would be obtained on the phantom. At the irradiation position, an **ICRU** slab dose equivalent (hereafter referred to as "apparent reference dose equivalent rate: $\dot{H}_0$") shall be obtained by the following formula.

$$\dot{H}_0 = \frac{I_0 \times N_0}{t_0}$$

Where N_0 : the calibration constant of the reference personal dosemeter, which was obtained by clause **3**

I_0: the indicated value of the reference personal dosemeter

t_0: irradiation time

b) A personal dosemeter to be calibrated which is the same type of dosemeter of **a)** shall be irradiated under the same irradiation conditions, and the indicated value (I) shall be obtained. The calibration constant (N) of a dosemeter to be calibrated shall be obtained by the following formula.

$$N = \frac{\dot{H}_0 \times t}{I} = \frac{I_0 \times t}{I \times t_0} \times N_0$$

Where $\dot{H}_0$: the apparent reference dose equivalent rate

N_0 : the calibration constant of the reference personal dosemeter

I_0 : the indicated value of the reference personal dosemeter

t_0 : irradiation time of the reference personal dosemeter

t : irradiation time of a dosemeter to be calibrated

Note (2) : The reference personal dosemeter must satisfy the requirements for the practical reference meter specified in **7.2** of the text.

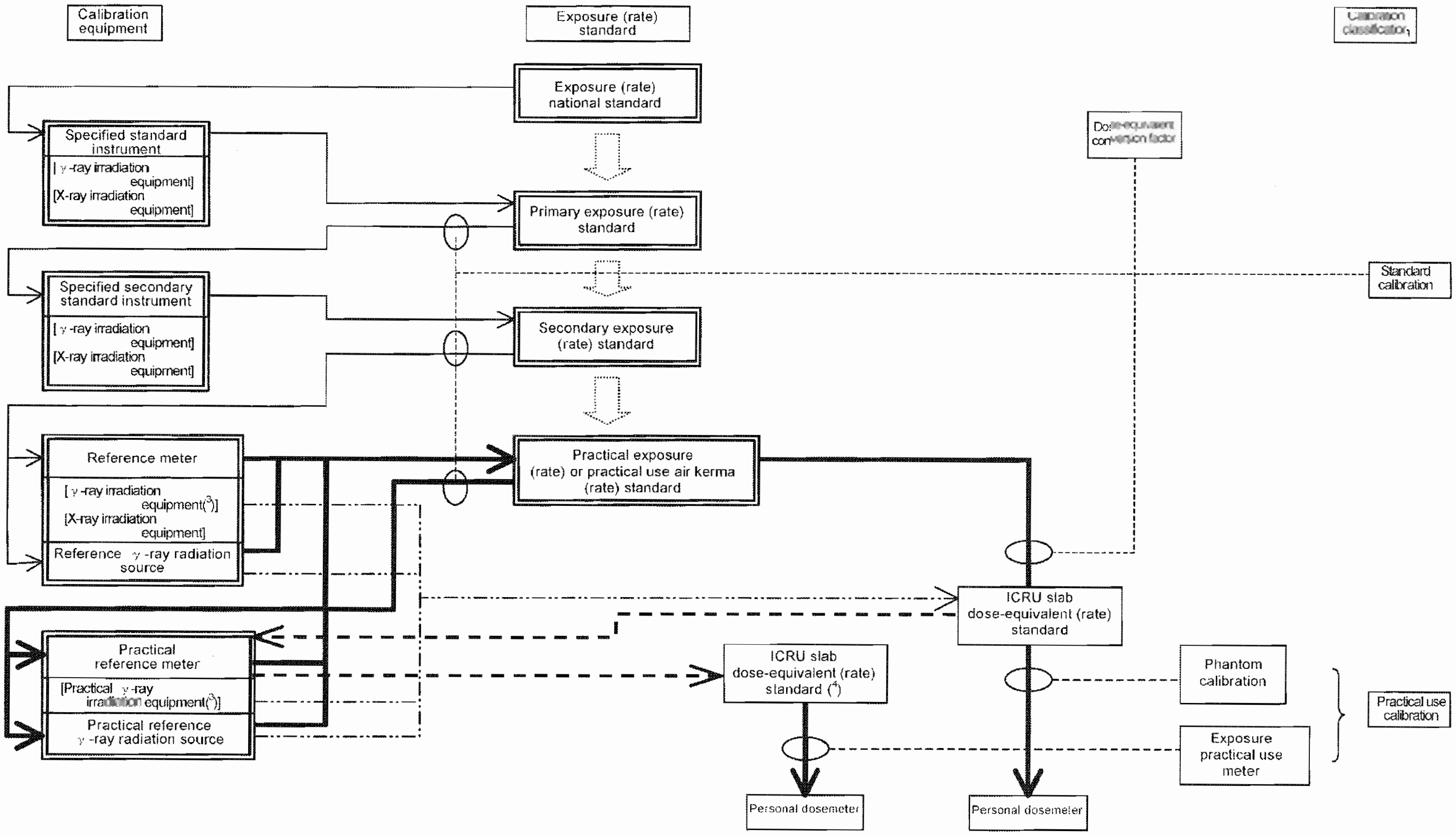
Remarks 1 The radiation source or practical γ -ray source of irradiation equipment shall be ^{137}Cs or ^{60}Co.

2 When a reference γ -ray source, a practical reference γ -ray source, or practical γ -ray irradiation equipment is used, if an **ICRU** slab dose equivalent rate ($\dot{H}_S$) at the irradiation position of a personal dosemeter is known, the procedure goes as follows. First, obtain the ratio [hereafter referred to as "conversion factor (q)"] between the indicated value (I_{OP}) when a reference personal dosemeter is installed on the phantom and the indicated value (I_{FA}) when a reference personal dosemeter is installed in the free space. Secondly, multiply the conversion factor by the indicated value (I_P) of a dosemeter to be calibrated, in order to obtain the apparent indicated value (I_C). Finally, the calibration constant (N_P) by the following formula may be obtained from I_C.

$$N_P = \frac{\dot{H}_S \times t}{I_C} = \frac{\dot{H}_S \times t}{I_p \times q}$$

Provided that,

$$I_C = I_P \times q \qquad q = \frac{I_{OP}}{I_{FA}}$$



Annex 1 Attached Figure 1　System of calibration of personal dosemeter

Notes (3) The air kerma (rate) of γ -ray irradiation equipment or a reference γ -ray source is multiplied by a dose-equivalent conversion factor, and it can be used as the irradiation equipment or the reference γ -ray source of the ICRU slab dose equivalent (rate). The value of practical γ -ray irradiation equipment is determined by the ICRU-sphere dose equivalent (rate), and a practical ICRU slab dose-equivalent (rate) standard can be set.

(4) A personal dosemeter is used as a practical reference meter, and it can set a practical ICRU slab dose-equivalent (rate) standard , and it can calibrated the personal dosemeter of the same type.

Remarks 1 Calibration of a specified secondary standard instrument and a reference meter (including practical reference standard) is outside of the scope of this Standard.

2 A solid line shows actual relation and the arrow of a bold dotted line shows relation of between a national standard and reference standard. A long dashed double-short dashed line shows the relation to a practical ICRU slab dose-equivalent (rate) standard.

Reference : An exposure (rate) standard is multiplied by an air kerma conversion factor, and it can be used as an air kerma (rate) standard.

Annex 1 Attached Figure 1 (concluded)

Annex 1 Attached Table 1 1 cm dose-equivalent conversion factor
(1 cm dose equivalent in connection with individual)

X-ray and γ-ray energy (5) MeV	Conversion factor from air kerma to 1 cm dose equivalent (6) Sv/Gy
0.010	0.009
0.012 5	0.098
0.015	0.264
0.017 5	0.445
0.020	0.611
0.025	0.883
0.030	1.112
0.040	1.490
0.045	1.645
0.05	1.766
0.06	1.892
0.08	1.903
0.10	1.811
0.125	1.696
0.15	1.607
0.20	1.492
0.30	1.369
0.40	1.300
0.50	1.256
0.60	1.226
0.66(7)	1.213
0.80	1.190
1.0	1.167
1.25(8)	1.149
1.5	1.139
3.0	1.117
6.0	1.109
10.0	1.111

Notes (5) When the energies of the X-ray and γ-ray emitted from a radiation source are a single energy, it is the photon energy. When the said energies are not a single energy, it is the effective energy.

(6) It is a conversion factor from an air kerma to the **ICRU** slab dose equivalent in the depth of 1 cm.

(7) It is the energy of a ^{137}Cs γ-ray.

(8) It is the energy corresponding to the equivalent conversion factor of ^{60}Co γ-ray.

Information : This table was based on **ICRP Publ.74.**

Annex 1 Attached Table 2 70μm dose-equivalent conversion factor (70μm dose equivalent in connection with individual)

X-rays and γ-ray energy (5) MeV	Conversion factor from air kerma to 70μm dose equivalent (9) Sv/Gy
0.005	0.750
0.010	0.947
0.015	0.981
0.020	1.045
0.025	1.130
0.030	1.230
0.040	1.444
0.045	1.546
0.050	1.632
0.060	1.716
0.080	1.732
0.10	1.669
0.15	1.518
0.20	1.432
0.30	1.336
0.40	1.280
0.50	1.244
0.60	1.220
0.66(7)	1.209
0.80	1.189
1.0	1.173

Notes (5) and (7) refer to note of Annex 1, attached table 1.

(9) It is a conversion factor from an air kerma to the **ICRU** slab dose equivalent of the depth of 70μm.

Information : This table was based on **ICRP Publ.74**.

Annex 2 (normative)
Calibration for confirmation of practical meter

1 Scope This Annex specifies the method of calibration for confirmation of a practical meter. The purpose of calibration for confirmation is to verify and confirm that the performance of a meter is maintained continually and that it is sufficiently accurate for the intended measurement which uses the said meter. The calibration for confirmation does not specify a new calibration constant to the said meter.

2 System of calibration for confirmation The system of calibration shall be specified in clause 4 of the text and the following:

a) Calibration for confirmation shall be, periodically or as necessary, performed about the practical meter having a definite calibration constant.

b) Calibration for confirmation can be carried out by defining a practical γ-ray source and irradiation conditions against a practical meter.

c) If a practical meter has been subjected to calibration for confirmation, and its calibration constant has been proven to be unchanged under the conditions specified by clause 4 of this Annex, then the said calibration constant can be used continually. However, if this condition is not satisfied, then a new calibration constant shall be determined based on the text.

Remarks 1 A user may specify the frequency of calibration for confirmation individually according to the performance of a meter, an intended use, operating conditions, etc. But, the frequency should be at least once a year.

2 The radiation source used for calibration for confirmation may or may not have a dose-rate standard. But, it should have intense enough to fully verify the validity of the calibration constant of a meter to be calibrated. In this case, it should be 30 % or over of the maximum scale within the range. In the case of the digital scale, the number of the second lowest digit should be 3 or over. Moreover, even when a meter to be used has plural measurement range, calibration for confirmation may be carried out at only a single measurement point of a single measurement range.

3 Method Calibration for confirmation shall be as follows. Use a practical meter having a definite calibration constant, and compare the value indicated after certain period of use since it was put in use, with the value indicated at the start by the same conditions of irradiation (hereafter referred to as "initial indicated value"). Irradiation shall be performed using the practical γ-ray source and irradiation conditions which were specified beforehand. Calculate the ratio between the value obtained and the initial indicated value. When obtaining the ratio of the indicated value at the time of calibration to the initial indicated value, use half-life compensation of a radiation source.

a) When calibration for confirmation is performed, it is necessary to retain the calibration record in which a radiation source used to the initial indicated value, irradiation conditions, etc. are described. The record shall be maintained to enable continual confirmation. An initial indicated value shall be obtained promptly after the calibration constant is defined. In the case of a stationary type meter, it shall be obtained promptly after installation at the place of use.

b) The γ-ray source used for calibration for confirmation must be a sealed radiation source which carries either ^{137}Cs or ^{60}Co, and which has a stable shape and a robust construction. Moreover, the same radiation source shall be used through the usable years of a meter. However, when it is exchanged unavoidably, the method of f) shall be followed.

Remarks 1 Depending on a meter, ^{226}Ra, ^{241}Am, or ^{90}Sr-^{90}Y radiation source may be used.

2 When a radiation source for inspection is beforehand built in the meter, the said radiation source may be used.

c) At the time of calibration for confirmation, the geometric arrangement conditions of the meter and the radiation source shall be the same as when an initial indicated value was obtained.

Remarks : As for geometric arrangement conditions, it should be set using the jig dedicated for each meter.

d) Calibration for confirmation shall be performed only after performing a visual examination of meter and function inspection (check) of detector and entire measuring part specified by manufacturers, and after confirming that there is no problem of functions.

e) At the routine measurement, the average of readings of several measurement is taken as the indicated value. In that case, the indicated value at the time of calibration for confirmation shall be obtained by performing the same number of measurements.

f) When the radiation source or irradiation conditions which are used for calibration for confirmation is changed, the calibration constant shall be determined again by the method specified in the text. However, calibration for confirmation may be performed continually in the following case. First, a meter to be calibrated is used. The radiation source and irradiation conditions are compared before change and after change. Secondly, the relation of indicated value against both is obtained with sufficient accuracy (with coefficients of variation within 0.05). Finally, it can be proven that the continuity from the initial indicated value is maintained.

4 Judgement of performance For calibration for confirmation, the range specified below is accepted to prove that the calibration constant has not changed. The ratio of indicated value obtained at the time of calibration for confirmation by the method specified in clause **3** of this Annex, to the initial value shall be in the range of 1 ± 0.1.

5 Record of calibration for confirmation The result of calibration for confirmation shall be described on the recording paper. The contents shall be as follows:

a) The name, model, serial number, calibration date; calibration personnel and calibration constant of a meter to be calibrated. As necessary, the record at the time of calibration (original calibration record) shall be attached.

b) The record when an initial indicated value was obtained shall include the following: an initial indicated value, the irradiation conditions when the initial indicated value was determined, the radiation source used (the nuclide and radiation-source number), implementation date, implementation personnel, and environmental conditions.

c) The record when calibration for confirmation was implemented shall include the following: the indicated value, judgement result, irradiation conditions, the radiation source (the nuclide and radiation-source number), an implementation date of calibration for confirmation personnel who implements calibration for confirmation, criteria of judgement, and environmental conditions.

Errata for JIS (English edition) are printed in *Standardization Journal,* published monthly by the Japanese Standards Association, and also provided to subscribers of JIS (English edition) in *Monthly Information.*

Errata will be provided upon request, please contact:

Standardization Promotion Department, Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN
TEL. 03-3583-8002 FAX. 03-3583-0462